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IRRIGATION of ORCHARDS

ORCHARD IRRIGATION in the arid and semiarid regions of this country varies in practice, according to water supply, climate, soil, and situation of the land, and in cost of installation and maintenance of the system.

The right selection of land for an orchard tract should be the irrigator's first step toward profitable fruit production.

Expensive devices should not be used for distributing water in orchards of low value and small returns, but valuable orchards, yielding large annual returns will justify the best-known devices for successful irrigation.

Prevention of waste of water should be a chief object of the irrigator not alone for the sake of economy but for the good of the orchard as well.

A discussion of the factors essential to the successful irrigation of orchards, as well as of different methods used, is presented in the following pages.

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IRRIGATION OF ORCHARDS.

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CONTENTS.

SELECTION OF LANDS FOR ORCHARDS.

CARE and good judgment should be exercised in the selection of an orchard tract. If the enterprise turns out well, the profits are high, but if it fails, the losses are heavy. It involves the setting aside of good land, the use of irrigation water, and somewhat heavy expenses in purchasing trees, setting them out, and caring for them until they begin to bear.

Assuming that the climate and soil of the district selected are adapted to the kind of trees to be grown, the next most important things to consider are good drainage and freedom from early and late frosts. Low-lying lands under a new irrigation system should be regarded with suspicion, even if the subsoil is quite dry at the time of planting. The results of a few years of heavy and careless irrigation on the higher lands adjacent may render the lowlands unfit for orchards. On the other hand, the higher lands are not always well drained naturally. A bank of clay extending across a slope may intercept percolating water and raise it near the surface. Favored locations for orchards in the mountain States often are found in the narrow river valleys at the mouths of canyons. The coarse soil of these deltas, the steep slopes, and the wind which daily blow first out of the canyons and then back into them, afford excellent conditions for the production of highly-flavored fruits at the minimum risk of being injured by frost.

Proper exposure is another important factor. In the warmer regions of the West and Southwest a northern exposure sometimes is best, but as a rule the orchards of the West require warmth and sunshine, and usually a southerly exposure is most desirable. Natural barriers frequently intercept the sweep of cold, destructive winds, and when these are lacking, windbreaks may be planted to serve the same purpose.

The elevation of the locality likewise should be considered. As a rule, the higher the elevation the colder the climate and the shorter the growing season. The principal reason why peaches can be grown as successfully at Penticton, British Columbia, as at Brigham, Utah, is that Penticton is less than 1,300 feet above sea level, and Brigham is more than 4,300 feet above. It is true also that the low-lying lands of any locality are the most subject to frost. Depressions or sheltered coves should not be selected for orchards if the cold air has a tendency to collect in them, a free circulation of air being necessary to drive away frost.

A severe frost that did great damage to the citrus orchards of southern California in the month of January, 1913, demonstrated that the most desirable locations as regards freedom from injurious frosts are to be found on the upper slopes of the valleys and comparatively near bluffs adjacent to depressions into which the cold air may settle.

Experience has shown that orchard trees of nearly all kinds can be grown successfully on soils that differ widely in their mechanical and chemical composition, and it has also shown that certain types of soils are best adapted to particular kinds of trees. Thus the best peach, almond, apricot, and olive orchards of the West are found on the lighter or sandier loams; the best apple, cherry, and pear orchards on heavier loams; whereas walnut, prune, and orange orchards do best on medium grades of soil. The requirements of all, however, are a deep, rich, and well-drained soil.

TYPICAL WATER SUPPLIES FOR ORCHARDS.

Formerly most western orchards were supplied with water through earthen ditches. These leaky, unsightly channels, by reason of their cheapness, would have been retained very generally had it not been for the increasing value and scarcity of water. The value of water for irrigation purposes has increased very materially in recent years. In many localities there is likewise great scarcity at certain times. These rapidly changing conditions have induced many water companies to prevent some of their heavy losses in conveying water by substituting pipes for open ditches in earth, or else by lining the ditches to make them water-tight.

The high value and scarcity of the water in natural streams likewise have induced orchardists to put in pumping plants to raise water from underground sources. It was estimated that over 30,000 of these plants were in operation in 1919 in California alone. In other parts of the West reservoirs are being built to supplement the late summer flow of streams which fail to provide enough water.

The few typical examples which follow may not only give the reader an idea of how orchards are supplied with water, but indicate also the customary division into tracts to serve this and other purposes.

Lewiston Basin is where Clearwater River flows into the Snake River in western Idaho, and varies from 700 to 1,900 feet above sea level. Some years ago water was brought from neighboring creeks and stored in a reservoir. The water required for orchard irrigation is conducted from this reservoir under pressure in two lines of redwood stave pipes over the rolling hills which separate the reservoir from the orchard lands. On these lands contour lines were first established, and each quarter section was afterwards divided into 40-acre

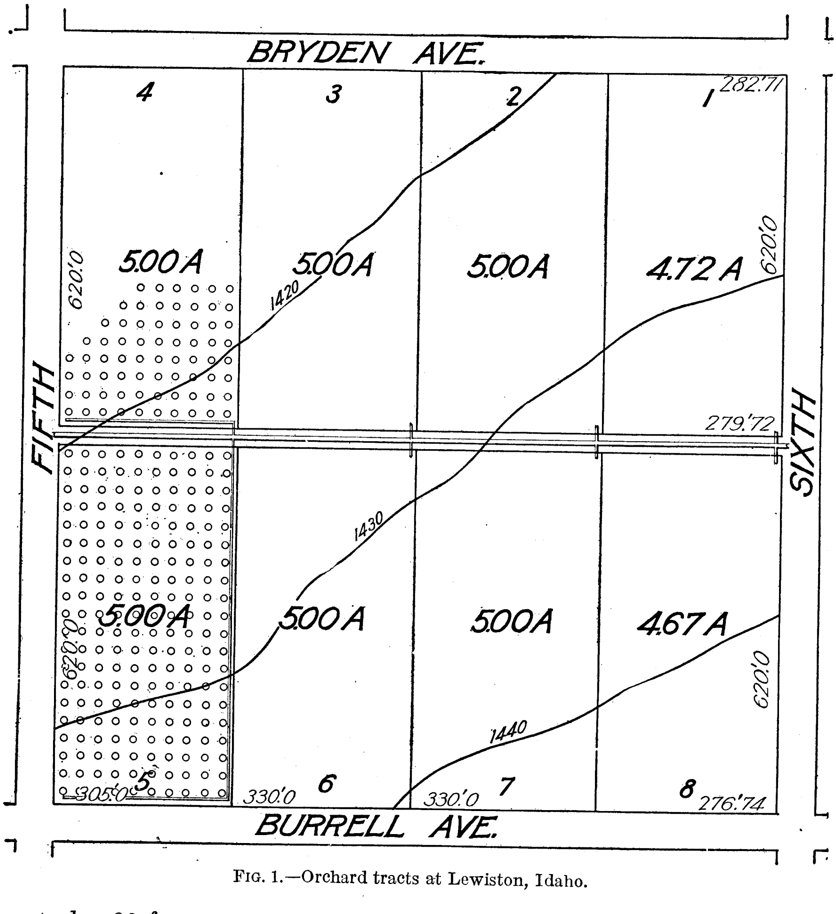

FIG. 1.—Orchard tracts at Lewiston, Idaho.

tracts by 60-foot streets. These were further subdivided into eight 5-acre tracts, with a 20-foot alley through the center. Figure 1, showing block 28 of the survey, indicates the general arrangement. The large conduits from the reservoir are connected to smaller lateral pipes laid in the alleys, and these in turn are tapped by 3-inch pipes, which furnish water to the 5-acre tracts.

The chief water supply for the lemon groves in the vicinity of Corona, Cal., comes from Perris Basin, 40 miles distant. The company owns 3,600 acres of water-bearing lands in this basin and

pumping plants have been installed at favorable points. These plants are operated by motors which formerly were supplied with current from a central generating station located at Ethenac, but in recent years the current has been purchased from the Southern Sierra Power Co., which transmits it across the Mojave Desert from Owens Valley.

Small lined channels convey the water from the pumps to the main conduit shown in cross section in figure 2. The concrete lining of this conduit is composed of one part cement to seven parts sand and gravel, having a thickness on the slopes of 2½ inches and on the bottom of 3 to 4 inches. The lining is made still more impervious by the addition of a plaster coat one-fourth of an inch thick, composed of one part of cement to two parts of sand. The cost was 5½ cents per square foot, or 55 cents per linear foot. The main conduit consists of about 30 miles of lined canal and 10 miles of piping 30 inches in diameter. As a rule the groves are laid out in 10 acre tracts, and piping of various kinds conveys the water from the main to the highest point of each tract, from which it is distributed between the rows in furrows.

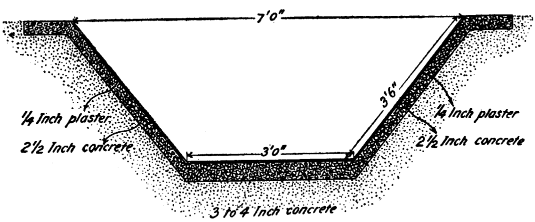

FIG. 2.—Concrete-lined canal of the Temescal Water Co.

A large part of the water used by the Riverside Water Co. is pumped from the gravelly bed of the Santa Ana River. Thence it is conveyed in a main canal to the orchard lands and distributed to the groves in cement and vitrified clay pipes. The owner of a tract, whether it be 10, 20, 30, or 40 acres in extent, receives his supply at the highest corner through a hydrant box. Each hydrant box not only allows the water to pass from the end of a lateral pipe to the head flume of the tract to be irrigated, but also measures the amount in miner's inches under a 4-inch pressure head as it passes through.

On the Gage Canal system in Riverside County, Cal., the water supply for the tiers of 40-acre tracts is taken from the canal in riveted steel pipes varying from 6 to 10 inches in diameter. These larger mains are connected with 4, 5, and 6 inch lateral pipes of the same material, which convey the water to the highest point of each 10-acre tract. This general arrangement is shown in figure 3.

The ditches conducting water from gravity canals to orchard tracts do not differ from the supply ditches for other crops which have been described in previous publications of this department.[1]

Various devices are used for the measurement of water applied to orchards. Where the water supply is conducted in open channels

[1] U. S. Dept. Agr., Farmers' Buls. 864 and 865.

some form of the weir is the most common. The simplest form of this device consists of a wall or bulkhead built across the channel, with an opening, called a weir notch, cut in the top. This weir notch may be rectangular, trapezoidal, or triangular in form, and in all three the water is measured as it pours through the notch. The triangular notch is the best suited for small discharges, running from 1 to 50 or more miner's inches. For larger quantities the rectangular weir is to be preferred. Full instructions pertaining to the proper manner of building and setting weirs, together with tables of weir discharges, may be found in Farmer's Bulletin 813.

When water is conveyed to orchards in pipes under pressure, the accurate measurement of the flow is more difficult and costly. In recent years a number of meters have been devised for this purpose, and of these mention may be made of the Venturi irrigation meter, the Binckley meter, the Grant-Mitchell, the Hill meter, the Reliance meter, and the Hanna meter. Several kinds of irrigation hydrants also have been devised, one of which is shown in figure 4 and another in figure 5.[1]

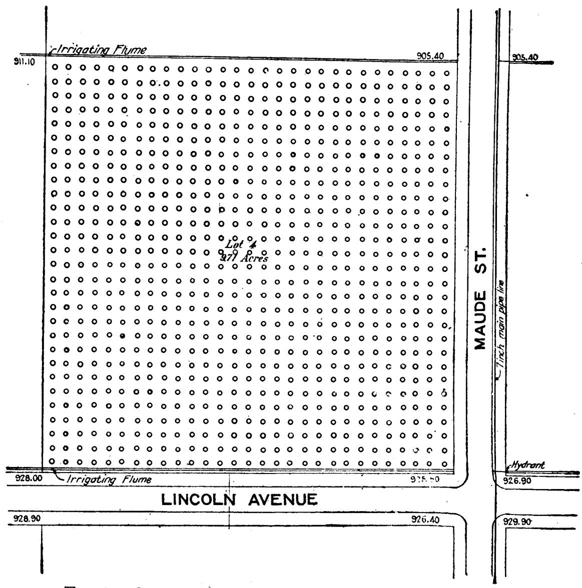

FIG. 3.—Orchard tract under Gage Canal, Riverside, Cal.

CLEARING AND GRADING LAND FOR FRUIT.

As a rule deciduous fruit trees are planted on land previously cultivated and cropped, but citrus fruit trees generally are planted on virgin soil. One of the best preparatory crops for deciduous orchards is alfalfa. This vigorous plant breaks up the soil and subsoil by its roots, collects and stores valuable plant foods, and when it is turned under at the end of the second or third year leaves the soil in much better condition for the retention of moisture and the growth of young trees.

In the Bitter Root Valley, Montana, new land is first plowed 8 to 12 inches deep, then carefully graded and smoothed and seeded to red clover for one or two seasons. On the west side of this valley pine

[1] For description of these hydrants see Bulletin 247 of the University of California.

trees and pine stumps are encountered. These can be removed best by burning. A hole $1\frac{1}{2}$ inches in diameter is bored through the base of the stump or tree in a slanting direction. It is near the surface of the ground on the windward side and about 18 inches above the surface on the leeward side. A fire is then built in the hole, using small twigs to start it. As the fire burns the opening is increased and larger limbs are inserted. In two or three days the stump will have burned out, the fire burning down into the roots to a depth of 12 to 14 inches. The cost of such clearing varies with the character

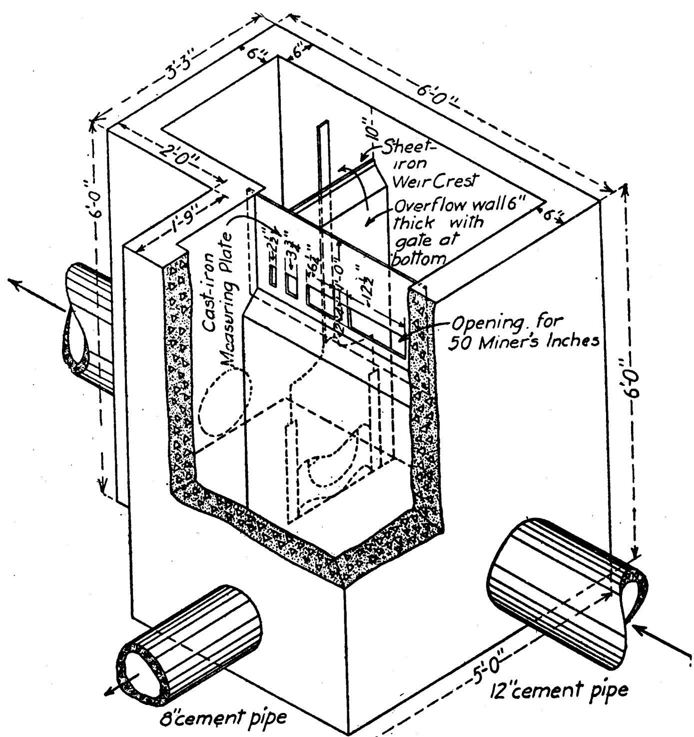

FIG. 4.—The Azusa irrigation hydrant.

of the land and the density of the growth and with local prices of labor.

Large areas of wooded lands in both the Hood River and Rogue River Valleys of Oregon have been cleared in order to plant apple trees. One of the methods employed in the Hood River district to rid the land of its growth of fir, pine, scrub oak, and laurel is similar to that just described. Another method consists in splitting open the stumps with giant powder and then pulling out the roots with a stump puller. Stump pullers of various kinds are used in California for a like purpose. The most powerful of these consists of a portable

engine, windlass, and cable similar to an ordinary hoisting plant. A heavy chain is fastened to the tree at the proper height above the ground. The pulling cable is hooked to this chain and when the power is applied the tree is pulled out by the roots.

In New Mexico and Texas the mesquite is grubbed out usually by Mexicans, but in California, where labor costs more, such shrubs as mesquite, manzanita, and chaparral can be removed more cheaply by a pair of stout horses and a logging chain.

In many of the later plantings of citrus orchards in southern California large quantities of bowlders and cobble are hauled from the land and piled in walls around the edges of the 10-acre tracts. The cost of removing the rocks sometimes reaches $100 per acre. Such lands are among the most desirable for citrus fruits because they are located near the foothills and at elevations where there is less frost than in the lower parts of the valley.

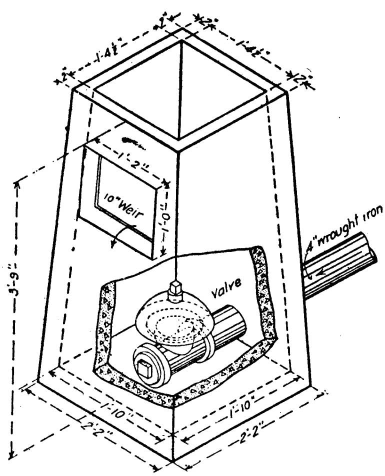

FIG. 5.—The Gage irrigation hydrant.

Devices for the removal of ordinary desert plants, such as sagebrush and grease wood, have been described in another bulletin.[1]

An effort should be made to establish a fairly uniform grade from top to bottom of each tract. This is done by cutting off the high points and depositing this earth in the depressions. The length of the furrows should not exceed one-eighth of a mile and in sandy soil they should be shorter. As a rule, it is not difficult to grade the surface of an orchard so that small streams of water will flow readily in furrows from top to bottom.

LOCATING THE TREE ROWS.

Before setting out orchards which are to be irrigated, the elevations of all parts of the surface of the ground should be ascertained. This is usually done by making a contour survey by which each tract is divided up by level lines into a number of curved strips or belts. Such contours are shown in figure 1, the vertical distance between them in this particular case being 1 foot. With these as a guide the direction of the tree rows can be determined readily. Where the trees are watered in basins or checks, flat slopes are not so objection-

[1] U. S. Dept. Agr., Farmers' Bul. 865.

able, but in furrow irrigation a slope of at least 2 inches to 100 feet is necessary to insure an even distribution of water. When streams are to be run in the furrows the slope of the furrows may be increased to 8, 10, and even to 12 inches to 100 feet. On slopes varying from 10 to 40 feet to the mile, the tree rows therefore may be located at the proper distance apart down the steepest slope. Under such conditions the trees usually are planted in squares. On steep slopes the trees usually are planted on graded curved lines so as to prevent furrow erosion and to facilitate the distribution of water along flatter slopes. The new plantings of citrus orchards at Riverside, Cal., on steep hill sides, are laid off on graded curved lines in which the fall ranges from 0.2 per 25 feet to 1 in 100 feet. (See illustration on title-page.) The Limoneria Company, of Santa Paula, Cal., has adopted a grade of 1.25 per cent for its lemon orchards, but the orange and lemon trees of the Mills orchards on the west side of the Sacramento Valley have a grade of 2 to 3 inches between trees, which are spaced 24 feet apart.

The location of the trees can be fixed best by the use of a surveyor's transit and steel tape. When these are not available, a woven-wire cable about three-sixteenths of an inch in diameter will answer the purpose. If apple trees are to be set out and it is desired to have them 32 feet apart, tags are inserted between the strands of the cable to mark this exact distance. A base line at the proper distance from the fence or one margin of the field is then laid down and long sighting stakes driven at each tag. The corner is then turned and a similar line is laid out. This process is continued until the location of the trees around each of the four sides of the tract has been fixed. The corners can best be turned with a 100-foot tape or link chain. First measure from the end of the base line a distance of 30 feet. Hold the one-hundred end of the chain at this point, and the 10-foot link at the corner; take the tape or chain at the 50-foot mark or link and pull both lines taut. A stake driven at this vertex will establish a point on a line at right angles to the first. When stakes have been set on all four sides, the intermediate locations for the trees can be ascertained readily by sighting between corresponding marginal stakes.

Where the slope is steep and difficulties are likely to be encountered in distributing water, the equilateral, hexagonal, or septuple method of planting, as it is variously termed, should be adopted. The manner of marking the ground for this method is indicated in figure 6. It will be observed that in this method the ground is divided up into equilateral triangles, with a tree at each vertex. The trees likewise form hexagons, and including the center tree of each hexagon they form groups of sevens. Hence the names equilateral, hexagonal, and septuple.

The chief advantage of this mode of planting in irrigated districts is that it provides three and often four different directions in which furrows may be run. Having the choice of so many, it is not difficult to select the one which is best for any particular tract. The ground likewise can be cultivated in more ways and about one-seventh more trees can be planted to a given area than is possible in the square method.

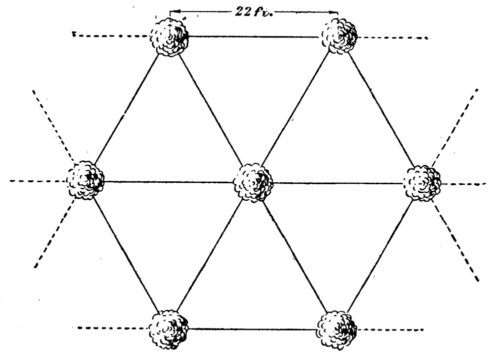

FIG. 6.—Hexagonal method of setting out orchard trees.

In the past the trees of irrigated orchards have been planted too close. This is made clear to even the casual observer who visits the old orange groves of Riverside, Cal., the deciduous orchards of the Santa Clara Valley, California, or the apple orchards of the Hood River district in Oregon. Under irrigation systems peach trees should be spaced 20 to 22 feet, olive, pear, apricot, and cherry trees from 22 to 28 and 30 feet, orange trees 22 to 24 feet, apple trees 30 to 36 feet, and walnut trees from 48 to 56 feet apart.

On the Pacific coast the tendency toward wide spacing has induced many growers to insert peach fillers between slower maturing trees, such as the apple and walnut. A common practice in this direction is shown in figure 7, which represents the arrangement of trees in an orchard in Douglas County, Wash. Here the trees are set in squares 18 feet each way, but in every other row peach trees alternate with the standard apple trees. In the remaining rows Winesap apple trees are used for fillers. As the apple trees grow and begin to crowd the fillers, the peach trees are removed. If more space is required the Winesaps can be taken out, leaving the apple trees in squares 36 feet apart both ways.

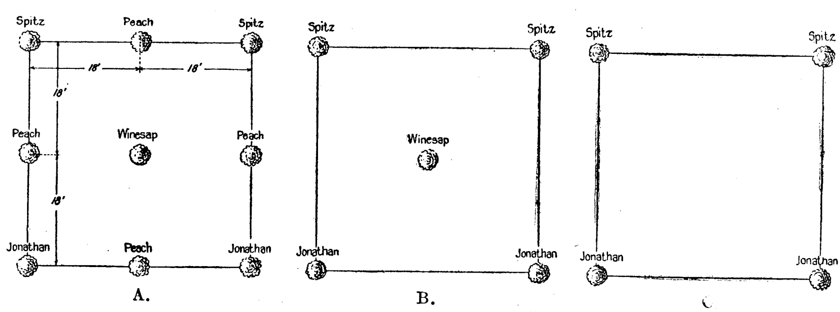

FIG. 7.—Plan of planting apple trees with peach trees as fillers; A, Trees as planted at first; B, peach trees removed; C, Winesap removed.

METHODS OF IRRIGATING ORCHARDS.

FURROW IRRIGATION.

The most common method of irrigating orchards is by means of furrows. These vary in depth, length, and distance apart to conform to local requirements arising from the character of the soil and surface, the quantity of water used, and other conditions. The manner of distributing water to the upper end of each furrow likewise varies in accordance with the efficiency of the irrigation system,

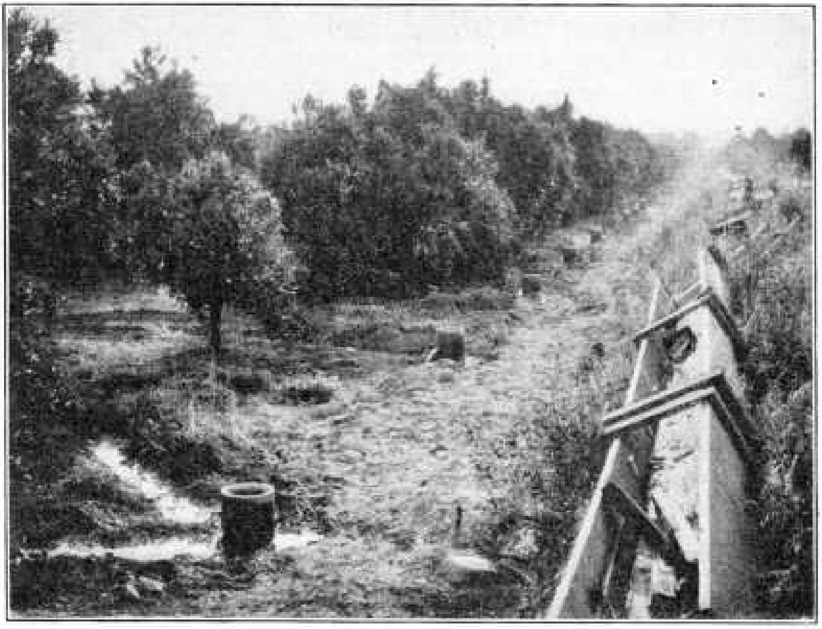

FIG. 8.—Discarded lumber head flume replaced by concrete pipe and stand system.

the amount of money expended, the skill used in installation, and the value and average annual profits of the orchard.

Expensive devices for distributing water into furrows are not warranted in orchards of little value and small annual returns. On the other hand, it may prove an economical investment to provide valuable orchards, yielding high annual returns, with the best known devices for successful irrigation. Such a device is unquestionably the concrete or other underground pipe fitted with suitable standpipes. At the other extreme is to be found the earthen ditch. Figure 8 shows a discarded lumber head flume replaced by a concrete pipe and stand system.

EARTHEN HEAD DITCHES.

Permanent ditches at the head of orchard tracts should be located by a surveyor. The proper grade depends chiefly on the soil. If the soil is loose and easily eroded, a slow velocity is best. On the

other hand, the velocity must be sufficiently rapid to prevent the deposition of silt and the growth of water plants. In ordinary soils, a grade of $2\frac{1}{2}$ inches to 100 feet for a ditch carrying 2 cubic feet per second is not far out of the way. The amount of water to be carried varies from $\frac{1}{2}$ to 2 or more cubic feet per second. A ditch having a bottom width of 24 inches, a depth of 6 inches, and sloping sides, ought to carry $1\frac{1}{2}$ cubic feet per second on a grade of half an inch to the rod or 3 inches to 100 feet. Such a ditch may be built by first plowing four furrows and then removing the loose earth with either shovels or a narrow scraper. The loose earth likewise may be thrown up on the sides and top by means of the homemade implement shown in figure 9. Canvas dams, metal tappoons, or other

FIG. 9.—The use of the "A" scraper in building head ditches.

similar devices are inserted in the head ditch to raise the surface of the water opposite that part of the orchard where furrows have been made and which is about to be watered. The chief difficulty in this mode of furrow irrigation arises in withdrawing water from the ditch and in distributing it equally among a large number of furrows. A skilled irrigator may adjust the size and depth of the ditch bank openings so as to secure a somewhat uniform flow in the furrows, but constant attention is required in order to maintain it. If the water is permitted to flow for a short time unattended the distribution is likely to become unequal. Parts of the ditch bank become soft, and, as the water rushes through, the earth is washed away, permitting larger discharges and lowering the general level of the water in the ditch so that other openings may have no discharge.

Some of the orchardists of San Diego County, Cal., insert in niches cut in the bank pieces of old grain sacks or tent cloth. The water flows over these without eroding the earth. Another device is to use a board pointed at the lower end and containing a narrow opening or slot through which the water passes to the furrow. Shingles are also used to regulate the flow in the furrows. The thin ends of these are stuck into the ground at the heads of furrows.

SHORT TUBES IN HEAD DITCHES.

Short tubes or spouts have been used in many of the head ditches of orchards to divert small quantities of water to furrows. These tubes usually are made of wood, but pipes made of clay, black iron, galvanized iron, and tin are used occasionally.

For nurseries and young trees especially, and also for mature trees, a cheap and serviceable tube may be made from pine lath, such as are used for plastering. The 4-foot lengths are cut into two equal parts and four of these pieces are nailed together to form a tube. One of these tubes when placed with its center 2 inches below the surface of the water in the head ditch discharges nearly three-quarters of a miner's inch of water, and if placed 4 inches below the surface will discharge more than 1 miner's inch. In southern Idaho the lumber mills manufacture a special lath for this purpose. It is ½ inch thick, 2 inches wide, and 36 inches long. If such tubes when thoroughly dry are dipped in hot asphalt they will last a much longer time. In some of the deciduous orchards of California a still larger wooden tube or box is used. Figure 10 represents one of these. It is made of four pieces of ¾ by 3¾ inch redwood boards of the desired length. The flow through this tube is regulated by a cheap gate, consisting of a piece of galvanized iron fastened by means of a leather washer and a wire nail.

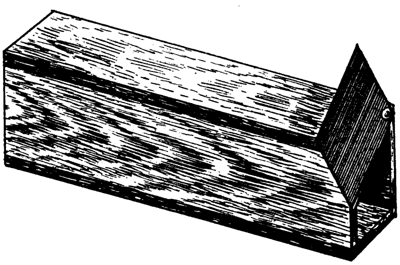

FIG. 10.—Wooden box placed in bank of head ditch.

The orchardist who lives near a manufacturing town or city can often purchase at a low figure pieces of worn-out and discarded piping varying from ¾ to 2 inches in diameter. Such pipes when cut into suitable lengths make a good substitute for wooden spouts. Tin tubes one-half inch in diameter and of the proper length have been used with good success. In compact soils, through which water passes very slowly, the furrows must be near together, and under such conditions small tin tubes are to be preferred.

In making use of tubes of various kinds to distribute water to furrows it is necessary to maintain a constant head in the supply ditch.

This is done by inserting checks at regular distances. These distances vary with the grade of the ditch, but 150 feet is not far from being an average spacing. In temporary ditches the canvas dam is perhaps the best check, but in permanent ditches it pays to use wood or concrete. An effective wooden check is shown in figure 11. In this the opening is controlled by a flashboard which may be adjusted so as to hold the water at any desired height and at the same time permit the surplus to flow over the top to feed the next lower set of furrows.

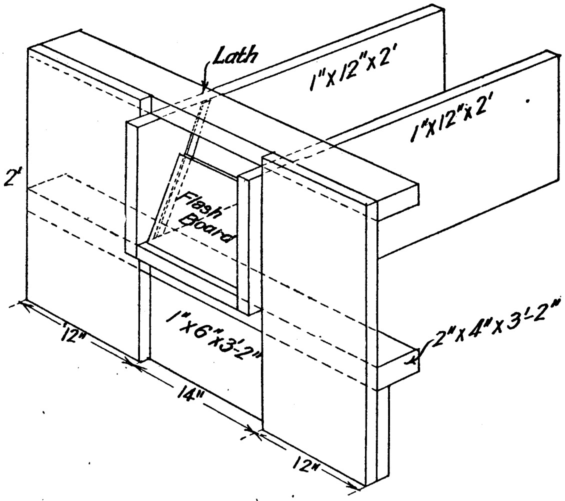

FIG. 11.—Wooden check in head ditch

HEAD FLUMES.

Formerly head flumes for orchards were built of wood, but the steady increase in the price of lumber and the decrease in the price of Portland cement have induced many fruit growers to use concrete instead. When built of wood, the length of the sections varies from 12 to 20 feet, 16 feet being the most common. The bottom width runs from 6 to 12 inches, and the depth usually is 1 to 2 inches less. Red-wood lumber $1\frac{1}{4}$ inches thick is perhaps the best for the bottom and sides, and joists of 2 by 4 inch pine or fir are commonly used for yokes which are spaced 4 feet centers. Midway between the yokes auger holes are bored and the flow through these openings is controlled in the manner shown in figures 12 and 13. A 2-inch fall for each hundred feet may be regarded as a suitable grade for head flumes, but it

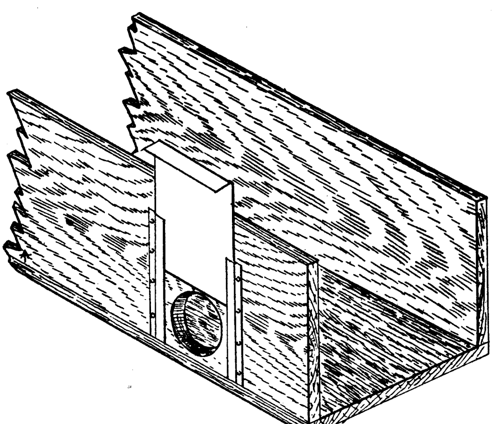

FIG. 12.—Section of wooden head flume, showing opening and gate.

often happens that the slope of the land is much greater than this, in which case low checks are placed in the bottom of the flume at each opening, as shown in figure 13.

A head flume composed of cement, sand, and gravel costs as a rule but little more than a wooden flume of the same capacity, and the early decay of wood, especially if it comes in contact with earth, makes the cement flume much cheaper in the end. By means of a specially designed machine, which is patented, cement mortar composed of one part cement to about six parts of coarse sand is fed into a hopper and forced by lever pressure into a set of guide plates cf the form of the flume. Such flumes are made in place in one continuous line across the upper margin of the orchard tract. After the flume is built and before the mortar has become hard, small tubes from $\frac{3}{4}$ to $1\frac{1}{2}$ inches in diameter, the size depending somewhat on the size of the flume, are inserted in the side next the orchard. The flow through these tubes is regulated by zinc slides shown in figure 13. Flumes of this kind are made in five sizes, the smallest being 6 inches on the bottom in the clear and the largest 14 inches.

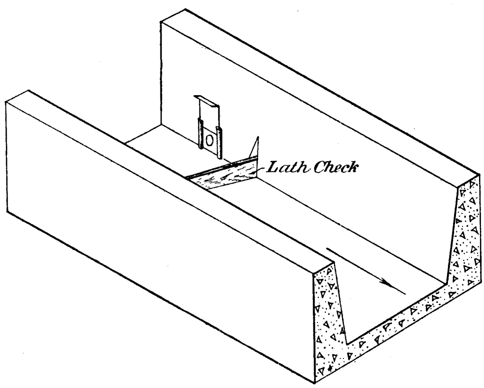

FIG. 13.—The use of low check in head flume.

At a slightly greater cost a stronger flume can be built by the use of molds. The increased strength is derived from a change in the mixture. In the machine-made flume the mixture of 1 part cement to 5 or 6 parts of sand is lacking in strength, because there is not enough cement to fill all the open spaces in the sand. In using molds medium-sized gravel can be added to the sand and the mixture resembles that of the common rich concrete.

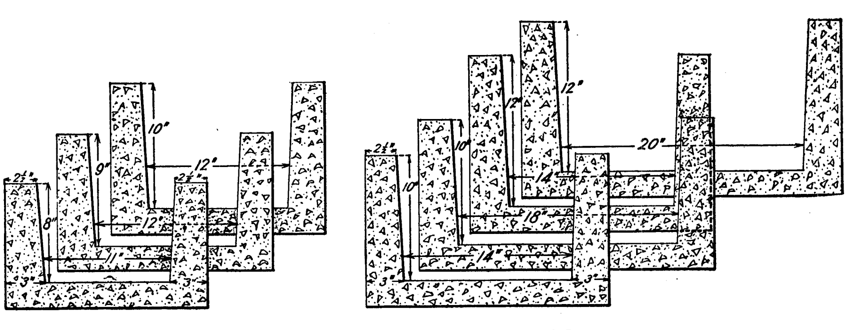

FIG. 14.—Common sizes of concrete head flumes.

Such flumes can be built of almost any size from a bottom width of 10 inches to one of 40 inches and from a depth of 8 inches to one of 24 inches, but when the section is increased beyond about 240 square inches it pays better to slope the sides outward and adopt the form of the cement-lined ditch. The quantity of concrete required per linear foot of flume depends on its size and the thickness of its sides and bottom. The dimensions given in figure 14 are for light rather than for heavy flumes and are designed for localities where there is little frost.

For large head flumes and laterals, many fruit growers first carefully prepare an earthen ditch which has carried water for at least one season and afterwards line the inner surface with cement concrete. Figure 15 shows a section of such a ditch.

Some years ago 3,200 linear feet of head ditches were lined for 26½ cents per foot; they were 14 inches on the bottom with 18-inch sides and a 2-inch lining. The cement cost $2.85 per barrel, gravel 75 cents per yard, and labor $1.75 to $2.50 per day. Present prices of both materials and labor are higher, but the prices quoted will give an idea of cost.

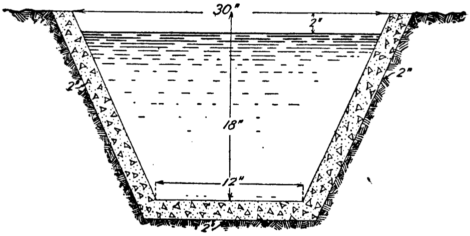

FIG. 15.—Earthen head ditch lined with concrete.

PIPES AND STANDPIPES.

Head flumes, being placed on the surface of the ground, interfere with the free passage of teams in cultivating, irrigating, and harvesting the crop. Dead leaves from shade and fruit trees also clog the small openings in the flumes. These and other objections to flumes have induced many fruit growers of southern California to convey the water in underground pipes and distribute it through standpipes placed at the heads of the rows of trees. Both cement and clay pipes are used for this purpose.

The cement pipes are usually molded in 2-foot lengths, with beveled lap joints, and consist of a 1 to 3 or 1 to 4 mixture of cement and fine gravel and sand. The most common sizes are 8, 10, and 12 inches in diameter, having a thickness of shell in the 12-inch pipe of 1½ inches which is reduced to a trifle more than 1 inch in the 8-inch pipe. Piping of this kind, when well made and carefully laid, will withstand a head of 25 to 40 feet.

The clay pipe is similar to that used for sewers in cities but usually has some minor defect which causes its rejection for that purpose. It is graded accordingly into Nos. 1, 2, and 3 pipe. Piping of No. 1 grade ordinarily can be expected safely to withstand heads up to 25 feet.

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A line of pipe is laid about 2 feet below the surface from the feed main and measuring box across the top of the orchard, and as each row of trees is passed a standpipe is inserted. The general plan is shown in figure 16. Various devices are employed to convey the water from the pipe to the surface of the ground at the head of each

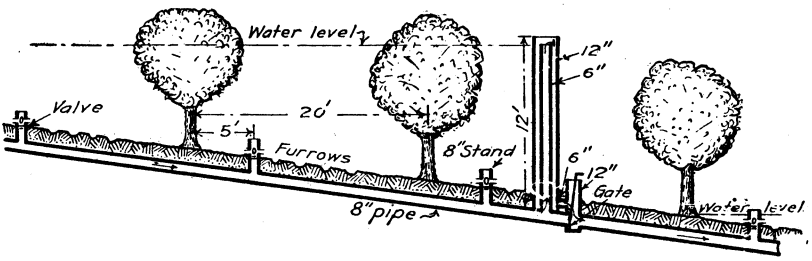

FIG. 16.—The use of underground pipe in furrow irrigation, showing risers and stand.

tree row and divide it up evenly among 4 to 6 furrows. One of the most common consists of a series of standpipes, the top of each set rising to the same elevation. At each change of elevation special standpipes are used, and in these are inserted gates provided with overflows. (Figs. 17 and 18.) The manner of distributing the water from a standpipe to the furrows of any one row is shown in figure 19.

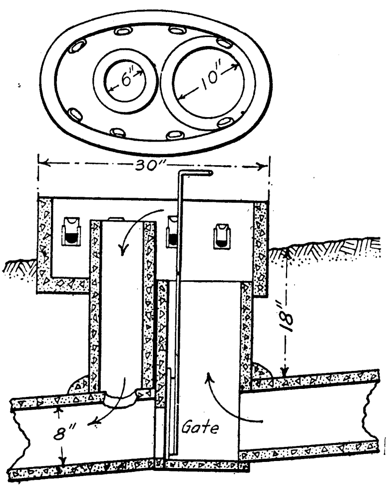

FIG. 17.—Standpipe used in distributing water to furrows.

Occasionally throughout the Rocky Mountain States a high-pressure pipe is substituted for cement and clay. This is tapped at the head and in line with each row of trees, and a small galvanized-iron pipe is inserted. These standpipes are capped by an ordinary valve which regulates the flow to each row of trees. This method is shown in operation in figure 20, where a young orchard is being irrigated from $\frac{3}{4}$-inch galvanized-iron standpipes connected to a 3-inch wooden pipe. It will be noted, however, that the water as it flows from the standpipes is not controlled properly, and proper devices should be introduced to check the velocity, distribute the water more equally to the several furrows, and prevent the erosion of the soil.

MAKING FURROWS.

The length of the furrow often is governed by the size of the orchard. The rows of citrus trees seldom exceed 40 rods in length, but the apple orchards of the Northwest are larger as a rule. Even

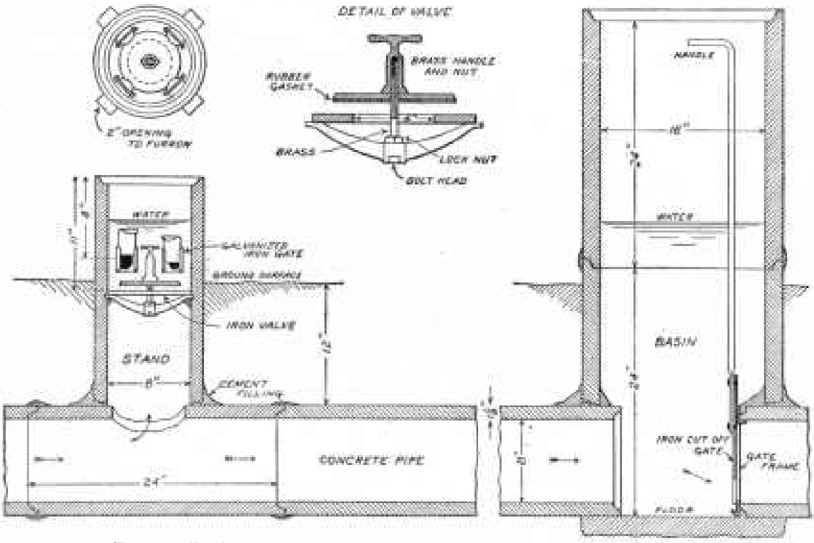

FIG. 18.—Design for concrete pipe and stand system for orchard irrigation.

FIG. 19.—Method of distributing water from standpipe to furrows.

in large tracts it is doubtful if it ever pays to run water in furrows more than about 600 feet. Where the soil is open and water sinks readily through it, short furrows should be used, otherwise much

water is lost in deep percolation on the upper part of the tract. Prof. H. Culbertson, of San Diego County, Cal., after a careful investigation of this subject has reached the conclusion that on sandy or gravelly soil having a steep slope the proper length of furrows is 200 feet, whereas on heavier soils and flatter slopes the length may be increased to 600 feet.

The grade of furrows varies quite widely. In flat valleys it often is not possible to obtain a fall greater than 1 inch to 100 feet, whereas on steep slopes the fall may reach 20 inches or more per 100 feet. On ordinary soils a grade of 3 to 4 inches is to be preferred, and where the fall exceeds 15 to 20 inches to 100 feet the trees should be set out in such a way as to decrease the slope of the furrows.

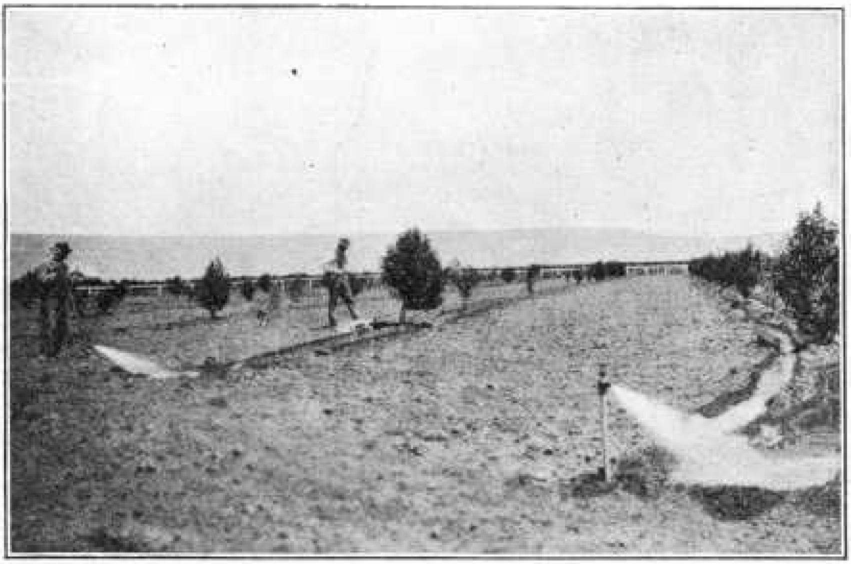

FIG. 20.—Method of irrigating from iron standpipes connected with pressure pipes.

The number of furrows in orchards depends on the age of the trees, the space between the rows, the depth of furrow, and the character of the soil. Nursery stock is irrigated by one or two furrows and young trees by two to four (fig. 21). A common spacing for shallow furrows is 2½ feet, but deeper furrows are made 3 to 4 feet apart (fig. 22). The general trend of orchard practice is toward deep rather than shallow furrows, a depth of 8 inches being used in many instances.

In spacing furrows chief consideration should be given to the lateral movement of moisture in the soil on each side of the furrows, so as to insure a fairly uniform distribution of moisture.

The furrowing implement most commonly used by the citrus orchardists of southern California consists of a sulky frame to which are

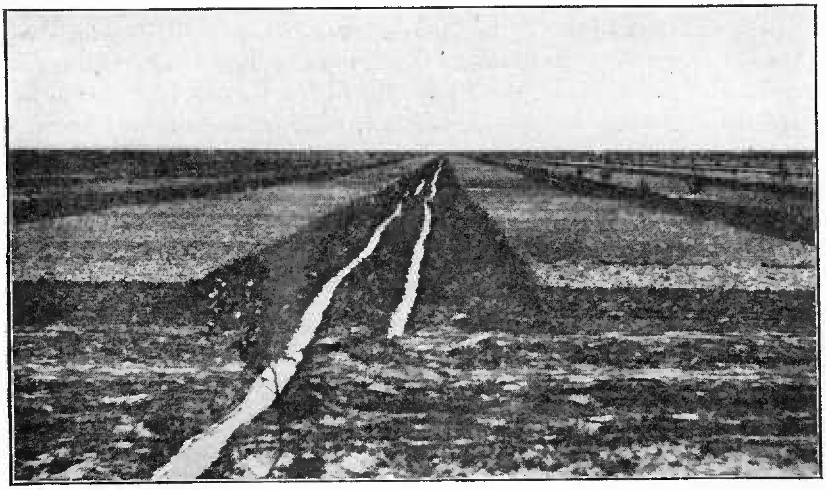

FIG. 21.—Irrigating young orchards in southern Idaho.

attached two or three double moldboard plows. Those who prefer a small number of deep furrows use a 12 to 14 inch corn lister. In figure 23 is shown a furrower made by attaching an arm to a cultivator and then fastening two shovels to the arm. In the view the space between the furrows is $4\frac{1}{2}$ feet and the depth is regulated by the lever arm of the cultivator.

APPLYING WATER TO FURROWS.

In the Payette Valley, Idaho, 200 or more miner's inches are turned into the head ditch and divided up by means of wooden spouts into

FIG. 22.—Usual method of irrigating orchards in Idaho.

a like number of furrows. On steep ground much smaller streams are used. The length of the furrow varies from 300 feet on steep slopes to 600 feet and more on flat slopes. The time required to moisten the soil depends on the length of the furrow and the nature of the soil. In this locality it varies from 3 to 36 hours.

A 20-acre orchard tract under the Sunnyside Canal in the Yakima Valley, Wash., is watered four times in each season with 14 miner's inches (0.35 cubic foot per second). Three furrows are made between the rows, which are 40 rods long. The total supply is applied to one-half the orchard (10 acres) and kept on 48 hours.

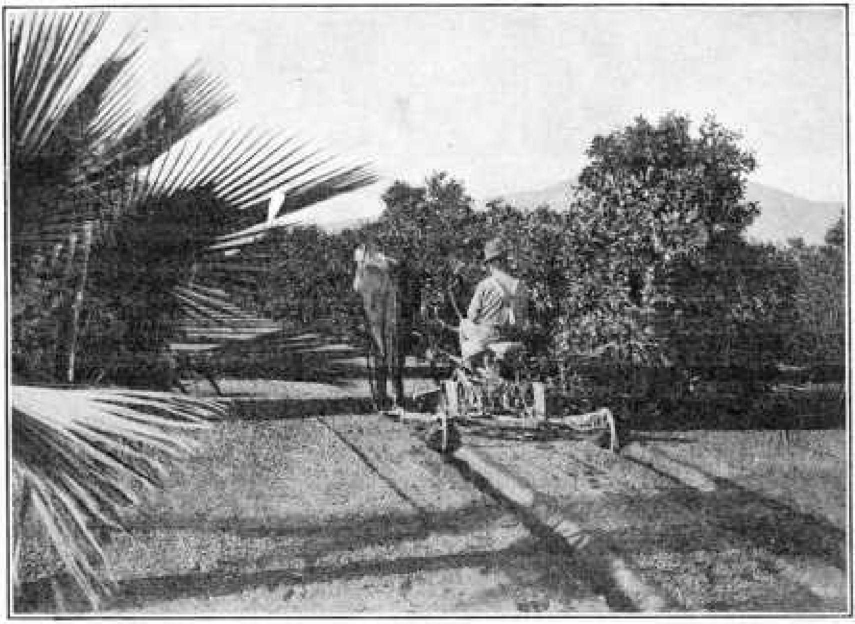

FIG. 23.—Making furrows in orchard.

On the clayey loams of the apple orchards on the east bench of the Bitter Root River, Mont., Prof. R. W. Fisher, formerly horticulturist of the Agricultural College of Montana, has found, as a result of experimenting, that it requires from 12 to 18 hours to moisten the soil in furrow irrigation 4 feet deep and 3 feet sideways.

In 1908 an orchardist of Hood River, Oreg., irrigated 3 acres of apple trees in furrows 350 feet long, spaced 3 feet apart. About a miner's inch of water was turned into each alternate furrow from a wooden head flume (fig. 12) and kept on for about 48 hours. After the soil had become sufficiently dry it was cultivated, and in 8 or 10 days thereafter water was turned into the alternate rows, which were left dry during the first irrigation.

For the most part, the furrows are made parallel to the rows of trees. An arrangement of this kind is satisfactory in young orchards, but as the trees reach maturity their branches occupy more of the open space between the rows and prevent the making of furrows near the trees. This is shown in figure 24, where a space of 6 to 12 feet square, according to the size of the trees, is not furrowed. This space usually becomes so dry that it is worthless as a feeding ground for roots. In order to moisten these dry spots, a larger stream often is carried in the two furrows next to each row of trees and the surplus is led across in short furrows in the manner shown in figure 25. Instead of continuing straight and cross furrows, as is done in figure 25, use is frequently made of

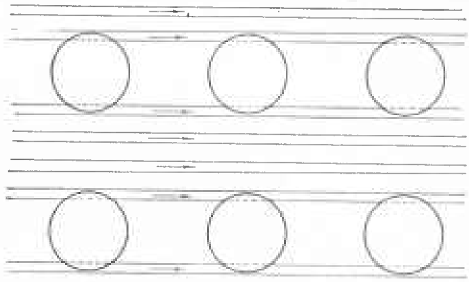

FIG. 24.—Furrow irrigation, showing dry spaces.

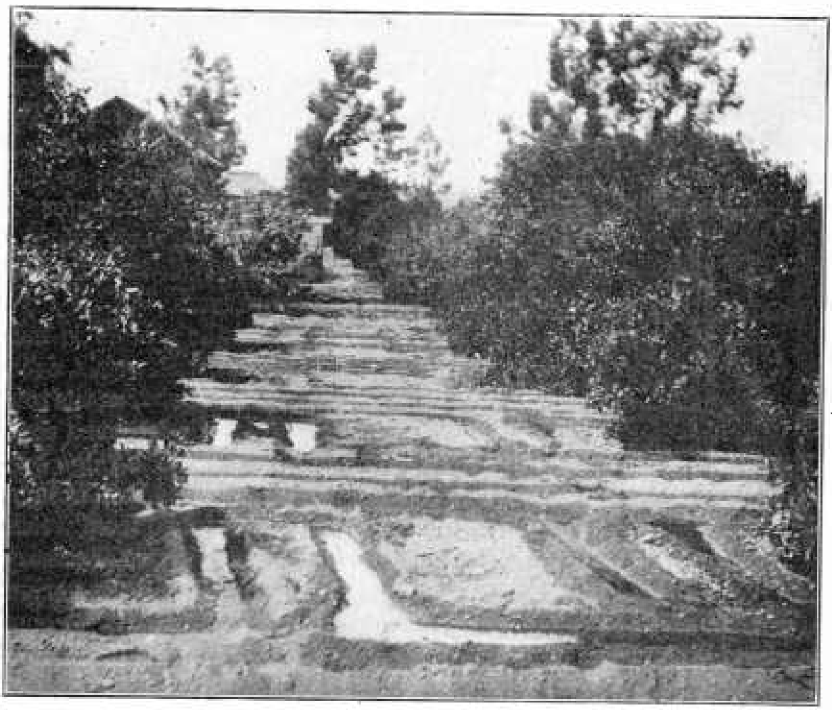

FIG. 25.—Cross-furrowing the dry spaces.

diagonal furrows to moisten the dry space between the trees. This last method is best adapted to grades of 5 inches to 100 feet or more.

A method and the cost of one irrigation is described as follows:

The implement used to make furrows consists of three shovels attached to a beam, which is mounted on a pair of low wheels.

The driver sits on a riding seat and by operating a lever can regulate the depth of the furrows. A man and two horses will furrow out 10 acres in a day. For a distance of 150 feet from the top of the orchard the furrows are straight. They are then zigzagged to within 60 or 70 feet of the bottom, where the last three rows of trees are irrigated by basins which catch the surplus. In the case described the depth of furrow was 6 inches, length 800 feet, and distance apart 3 feet. A head of 50 miner's inches (1 cubic foot per second) was used on 10 acres. The streams when first turned into the furrows averaged about 2 miner's inches, but as the water approached the lower end they were reduced to 1 miner's inch or less, and this flow was run in each furrow for 12 to 24 hours.

The items of cost for 10 acres were as given below:

Making furrows and basins	\$6.50
Irrigating	3.00
Fifty inches of water, 24 hours, at 40 cents an hour	9.60
Rent of water stock	12.00
Total	31.10

The increased cost of water and the present high prices of labor would increase this cost considerably.

THE BASIN METHOD.

Orchards sometimes are irrigated by first forming ridges midway between the rows in two directions at right angles to each other. This divides up the tract into a large number of squares with a tree in the center of each, as may be observed in figures 26 and 27. In rarer cases a basin or check incloses four or more trees.

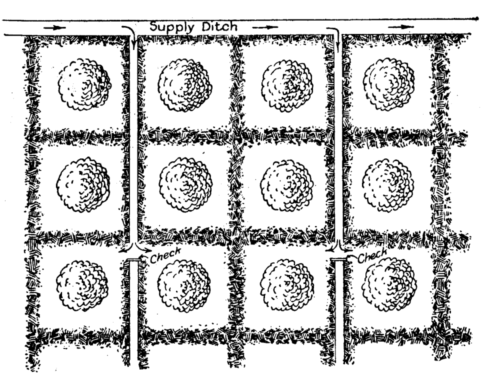

FIG. 26.—Basin method of irrigation.

When the ground is hard or covered with weeds, a disk plow is run between the rows and then the loosened earth is formed into a ridge by a ridger. If the soil is light, sandy, and free from weeds, the disking is not necessary. Ridgers are made in various ways of both wood and steel or some combination of both. A common kind is shown in figure 28. It consists of two deep runners 14 to 18 inches high, 2 inches thick, and 6 to 8 feet long. These runners are shod with steel which extends part way up the inner side. They are 4 to 5 feet apart at the front end and tapered to 16 to 24 inches at the rear. The runners are held in position by cross pieces on top, a floor, and straps of steel in the manner shown. Figure 29 shows a steel ridger which is used for the same purpose and in the same manner as the steel-shod wooden ridger shown in figure 28.

The height of the ridges varies with the depth of water applied, which is from 4 to 9 inches. The ridges should be several inches above the surface of the water when a basin is flooded.

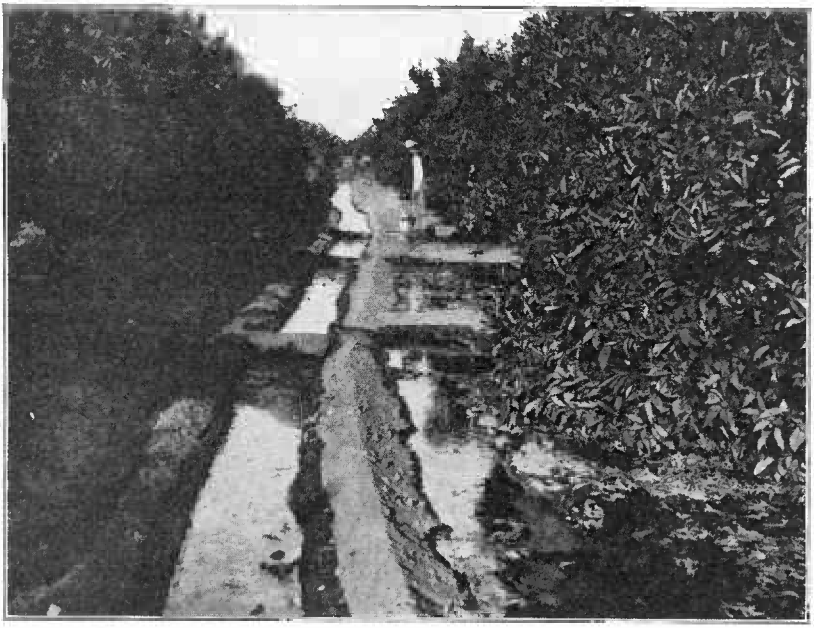

FIG. 27.—View of orchard being irrigated by basin method.

Several methods of flooding basins are practiced. In one a ditch is run from the supply ditch at the head through each alternate row space and the basins on each side are flooded in pairs, beginning with the lowest. This plan is shown in outline in figure 27. In the other method water is allowed to flow through openings into each basin of a tier in a zigzag course from the top to the bottom of the orchard. In this plan the upper basins receive the most water. Under gravity canals, where water is abundant, the water is turned into the upper basin until it is full, when it overflows into the next, and so on down the tier. The irrigator then begins at the lower end and repairs the breaks, leaving each basin full of water.

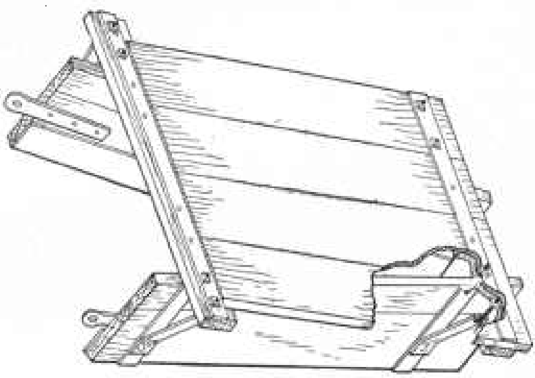

FIG. 28.—Adjustable ridger.

Interest in basin irrigation has been renewed of late in California owing to the fact that by this method of preparing land and applying water it has been found possible to mulch each basin throughout the dry season with cured alfalfa, bean straw, or other leguminous product. The soluble ingredients of such a mulch are carried by the irrigation water into the soil and in this way both food and moisture are furnished to the tree. This is a revival of a very old practice. Ibn el Awam, or Abu Zacaria, as he is called otherwise, who wrote in the twelfth century, speaks many times of mulches of straw, preferably bean stalks, in his book on agriculture.[1] The same author in another part of his work gives the following advice:

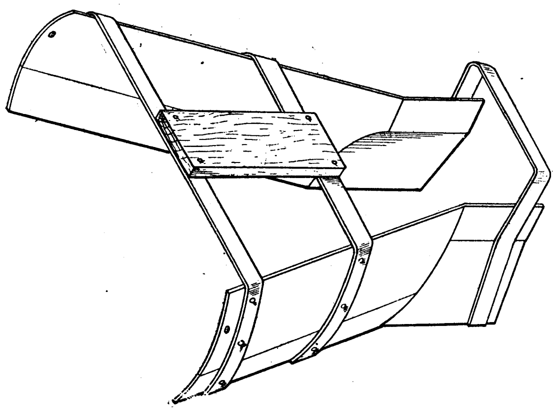

FIG. 29.—Steel ridger.

> You next take bean stalks with the beans stripped off, coming from the crop of the previous year and quite large. They are thrashed so as to reduce them to the state of very fine straw. This straw is spread in abundance on the soil after plowing and you irrigate on top of it.

Guillochan[2] says that it is excellent orchard practice after rotted manure has been spaded in early in the spring and the basins (cuvettes) have been formed for receiving irrigation to fill the latter with straw manure or, if this is not to be had, with dry grass.

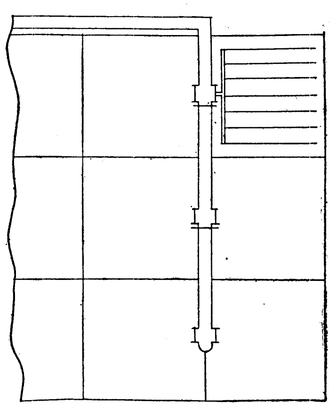

FIG. 30.—Combination of check and furrow methods.

THE CHECK METHOD.

Where the check method is practiced it frequently happens that land on which alfalfa has been grown is planted to fruit trees. In plowing down the alfalfa and setting out the trees, the levees undergo little change and the checks can be flooded if it is considered best. A better plan is to furrow the floor of each check as shown in figure 30. The water is admitted through the check box which was used for the alfalfa and conducted

[1] Kitab al-Felahah; translated into Spanish by José Bangueri, Madrid, 1802, and into French by J. H. Clement-Mullet, Paris, 1864–1866.

[2] Traité paratique d'horticulture pour le Nord d'Afrique, Paris, 1907, p. 185.

into a short head ditch, from which it is distributed to the furrows. The chief objection to this method is that the checks are too small for orchard tracts in furrow irrigation.

TIME TO IRRIGATE ORCHARDS.

The best orchardists believe that frequent examination of the stem, branches, foliage, and fruit is not enough. The roots and soil should be examined also. The advice of such men to the inexperienced is: Find out where the bulk of the feeding roots is located, ascertain the nature of the soil around them, and make frequent tests as to the moisture which it contains. In a citrus orchard of sandy loam samples are taken at depths of about 3 feet, and the moisture content determined by exposing the samples to a bright sun for the greater part of a day. It is considered that 6 per cent by weight of free water[1] is sufficient to keep the trees in a vigorous condition.

Doctor Loughridge, of the University of California, in his experiments at Riverside, Cal., in June, 1905,[2] found an average of 3.5 per cent in the upper 2 feet and an average of 6.16 per cent below this level in an orchard which had not been irrigated since October of the preceding year. It had received, however, a winter rainfall of about 16 inches. On examination it was found that the bulk of the roots lay between the first and fourth foot. These trees in June seemed to be merely holding their own. When irrigated July 7 they began to make new growth. A few days after the water was applied the percentage of free water in the upper 4 feet of soil rose to 9.64 per cent. The results of these tests seem to indicate that the percentage by weight of free moisture [1] should range between 5 and 10 per cent in orchard loams.

Many fruit growers do not turn on the irrigation stream until the trees begin to show visible signs of suffering, as a slight change in color or a slight curling of the leaves. In thus waiting for these signals of distress, both trees and fruit are liable to be injured. On the other hand, the man who ignores these symptoms and pours on a large quantity of water whenever he can spare it, or when his turn comes, is likely to cause greater damage by an overdose of water.

NUMBER OF IRRIGATIONS PER SEASON.

For nearly half the entire year the fruit trees of Wyoming and Montana have little active, visible growth, whereas in the citrus districts of California and Arizona the growth is continuous. A tree when dormant gives off moisture, but the amount evaporated from both soil and tree in winter is relatively small, owing to the low temperature, the lack of foliage, and feeble growth. A heavy rain

[1] The expressions "free water" and "free moisture" here used do not include any hygroscopic moisture.
[2] U. S. Dept. Agr., Office Expt. Stas. Bul. 203.

which saturates the soil below the usual covering of soil mulch may take the place of one artificial watering, but the light shower frequently does more harm than good. The number of irrigations likewise depends on the capacity of the soil to hold water. If it readily parts with its moisture, light but frequent applications will produce the best results; but if it holds water well a heavy application at longer intervals is best, especially when loss by evaporation from the soil is prevented by the use of a deep soil mulch.

In the Yakima and Wenatchee fruit-growing districts of Washington the first irrigation usually is given in April or early in May. Then follow three or four waterings at intervals of 20 to 30 days. At Montrose, Colo., water is used three to five times in a season. At Payette, Idaho, the same number of irrigations is applied, beginning about June 1 in ordinary seasons and repeating the operation at the end of 30-day intervals. As a rule, the orchards at Lewiston, Idaho, are watered three times, beginning about June 15. From two to four waterings suffice for fruit trees in the vicinity of Boulder, Colo. The last irrigation is given on or before September 5, so that the new wood may have a chance to mature before heavy freezes occur. In the Bitter Root Valley, Montana, young trees are irrigated earlier and oftener than mature trees. Trees in bearing are, as a rule, irrigated about July 15, August 10, and August 20 of each year.

In southern California citrus trees are watered six to seven times at regular intervals during the summer season with one to three additional irrigations in winter if cover crops are grown or if the rainfall is light. Deciduous orchards in the same locality are watered two to four times each season although occasionally one is found that receives only one irrigation, but it has been demonstrated that better results are secured with several irrigations.

DUTY OF WATER IN ORCHARD IRRIGATION.

The duty of water for 1 acre as fixed by water contracts varies all the way from one-fortieth to one four-hundredth of a cubic foot per second. In general, the most water is applied in districts that require the least. Wherever water is cheap and abundant the tendency seems to be to use large quantities, regardless of the requirements of the fruit trees. In Wyoming the duty of water is seldom less than at the rate of a cubic foot per second for 70 acres. In parts of southern California the same quantity of water not infrequently serves 400 acres, yet the amount required by the fruit trees of the latter locality is in excess of that of the former.

All over the West the tendency is toward a more economical use of water, and even in localities where water for irrigation is still reasonably low in price it is rare that more than 2½ acre-feet per acre is applied in a season. This duty was provided for in contracts of the

Bitter Root Valley Irrigation Co., of Montana, with 40,000 acres of fruit lands under ditch. Since, however, the water user is not entitled to receive more than one-half of an acre-foot per acre in any one calendar month, it is only when the growing season is long and dry that he gets the full amount.

In the vicinity of Boulder, Colo., the continuous flow of a cubic foot per second for 105 days serves about 112 acres of all kinds of crops. This amount of water, if none were lost, would cover each acre to a depth of 1.9 feet. In other words, the duty of water is a trifle less than 2 acre-feet per acre.

In 1908 the depth of water used on a 21½-acre apple orchard at Wenatchee, Wash., was measured and found to be 23 inches. The

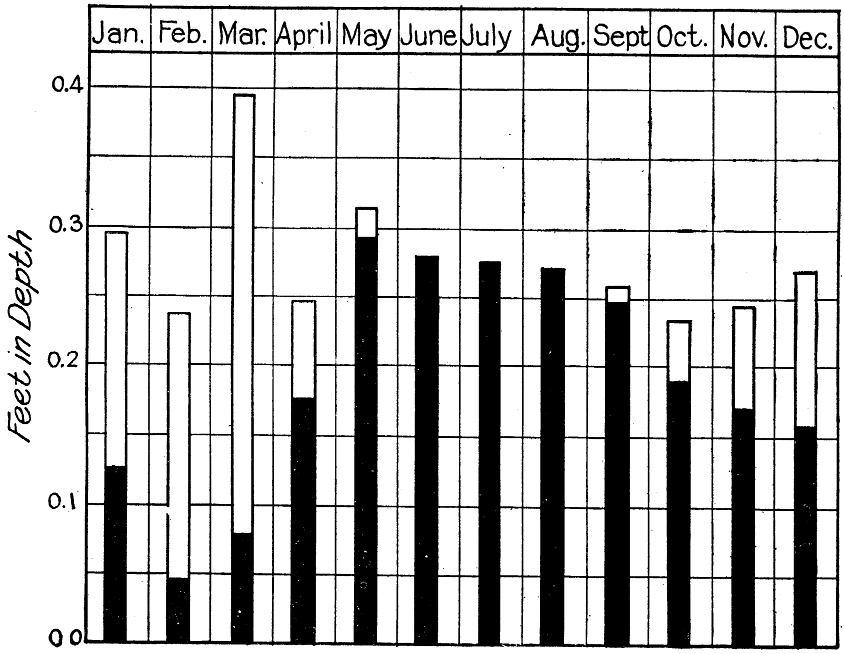

FIG. 31.—Average duty per month under Riverside Water Co., December 1, 1901, to November 30, 1908. Solid black bars indicate depth of water used, open bars rainfall.

trees were 7 years old and produced heavily. This orchard was watered five times, the first on May 13 and the last on September 23. In San Diego County, Cal., one miner's inch (one-fiftieth of a cubic foot per second) irrigates from 6 to 7 acres near the coast where the air is cool and evaporation low, but 20 miles or so inland the same amount of water is needed for about 4 acres.

On the sandy loam orchards of Orange County, Cal., it has been demonstrated that 2 acre-inches every 60 days is insufficient to keep bearing trees in good condition. The rainfall of this locality averages somewhat less than 12 inches per annum, but about 95 per cent of the total falls between November and May, inclusive.

The most reliable and in many ways the most valuable records pertaining to duty of water on orchards have been obtained in southern California. Here more or less irrigation water is used every month of the year. Figure 31 is a graphic representation of the average amount of water used per month in a period of seven years by the Riverside Water Co. in irrigating about 8,400 acres, of which about 4,500 acres are planted to oranges and the remainder to alfalfa. The figures given in the diagram represent depth in feet over the surface watered. The following table gives the average duty of water per month in acre-feet per acre under the same system from December 1, 1901, to November 30, 1908, a period of seven years. The table also includes the average monthly rainfall at Riverside, Cal., for the same period, and adding the quantity of water applied in irrigation in any one month to the rainfall of that month gives the total moisture received by the soil.

Water used under Riverside Water Co.'s system (1901–1908).

Month.	Average depth per acre.	Average rainfall.	Total water applied.	Month.	Average depth per acre.	Average rainfall.	Total water applied.
	Feet.	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
December	0.159	0.109	0.268	July	0.272	0.002	0.274
January	.123	.170	.293	August	.269	....	.269
February	.046	.190	.236	September	.243	.015	.258
March	.078	.316	.394	October	.189	.043	.232
April	.177	.068	.245	November	.169	.073	.242
May	.291	.023	.314				
June	.274	.003	.277	Total	2.29	1.01	3.30

The duty of water for citrus orchards in the vicinity of Pomona, Cal., was ascertained on a number of typical tracts during the summer of 1905 and the results are given in the following table:[1]

Duty of water for citrus fruits at Pomona, Cal., 1905.

Number of tract.	Crop.	Acres.	Irrigations.	Hours pumped.	Rate of pumping.	Depth applied by pumping.	Total, including rainfall.
					Miner's inches.	*Feet.*	*Feet.*
1	Young oranges	70.00	4	440	16	0.2	2.5
2	....do	10.00	7	1,560	2	.6	2.9
3	Oranges	30.00	5	550	23	.7	3.0
4	....do	36.50	5	507	16	.4	2.7
5	....do	60.00	5	1,100	28	.9	3.2
6	....do	20.00	5	500	24	1.0	3.3
7	....do	24.75	2	180	15	.2	2.5
8	....do	8.00	6	365	7	.5	2.8
9	....do	5.66	5	300	16	1.5	3.8
10	....do	4.25	5	75	43	1.3	3.6
11	Oranges and lemons	35.00	5	593	29	.8	3.1
12	Lemons	15.00	6	720	12	1.0	3.3
	Average	....	....	....	....	.8	3.1

[1] The Use of Underground Water for Irrigation at Pomona, Cal., by C. E. Tait, U. S. Dept. Agr., Office Expt. Stas. Bul. 236.

Tracts 1 and 2, being in young trees, did not require as much water as full-grown trees. Tracts Nos. 1, 2, 3, and 12 are in loose, gravelly loam near the foothills and No. 11 is in similar soil near San Dimas. Tract No. 10 is in tight soil near Spadra and the others are in the medium sandy loams near Pomona and Lordsburg. It does not appear that the unequal amounts of water applied to these tracts has been due to the different requirements of soils, but rather to the amount of water available.

For the seasons 1906, 1907, 1908, and 1909 the general duty for citrus fruit is represented by the amounts used under the systems of the Del Monte Irrigation Company and the Palomares Irrigation Company. All of the land under the Del Monte system and three-fourths of the land under the Palomares system is in citrus fruits. The results are based on the total number of hours that one or more heads of water are delivered. The average aggregate heads, in miner's inches, delivered in 1907 by the Del Monte Irrigation Company, were increased by a good supply of flowing water. An attempt is made to maintain constant heads, but usually they are slightly less than they are intended to be. This counteracts in a measure the error that would occur from making no deduction in the total acreage served by the companies for buildings and roads.

Duty of water, Pomona, Cal., 1906–1909.

DEL MONTE IRRIGATION COMPANY SYSTEM.

Year.	Acres.	Number of rotations.	Hours in schedule.	Size of stream.	Depth applied.	Total, including rainfall.
				Miner's inches.	*Feet.*	*Feet.*
1906	2,000	7	636	200	0.73	3.22
1907	2,000	7	636	300	1.10	2.98
1908	2,000	7	636	200	.73	2.19
1909	2,000	7	636	200	.73	3.39
Average					.82	2.94

PALOMARES IRRIGATION COMPANY SYSTEM.

Year.	Acres.	Number of rotations.	Hours in schedule.	Size of stream.	Depth applied.	Total, including rainfall.
1906	600	6	720	60	0.71	3.20
1907	600	7	720	60	.83	2.71
1908	600	7	720	60	.83	2.29
1909	600	7	720	60	.83	3.49
Average					.80	2.92

EVAPORATION LOSSES FROM ORCHARD SOILS.

A light shower followed by warm sunshine may refresh the foliage of fruit trees, but its effect on the soil is more likely to be injurious than otherwise. A brief, pelting rain followed by sunshine forms a crust on the surface of most soils, and if this is not soon broken up by cultivation it checks the free circulation of air in the soil and also tends to increase the amount of water evaporated.

It has been found[1] that the amount of moisture held by the soil, the temperature of both soil and air, and the rate of wind motion are the chief factors in the evaporation of water from soils. The influence of moisture is shown in the following figures, obtained from tank experiments made at Tulare, Cal., in 1904:

Evaporation from Tulare soils which received different amounts of water, June 15 to to Sept. 15, 1904.

Numbers of tanks.	Amount of water applied, inches.	Loss by evaporation.		Numbers of tanks.	Amount of water applied, inches.	Loss by evaporation.	
		Inches.	Per cent.			Inches.	Per cent.
1 and 2	0.0	0.45	....	7 and 8	6.6	5.5	83.6
3 and 4	3.3	3.5	106.0	9 and 10	8.2	6.6	80.0
5 and 6	4.9	4.6	94.0	11 and 12	9.8	7.9	79.5

The results of other experiments have shown that when the water is applied to the surface of orchard soils the loss by evaporation is very great so long as the top layer remains moist.

Even in light irrigations this loss in 48 hours after the water is put on may amount to from 10 to 20 per cent of the volume applied and

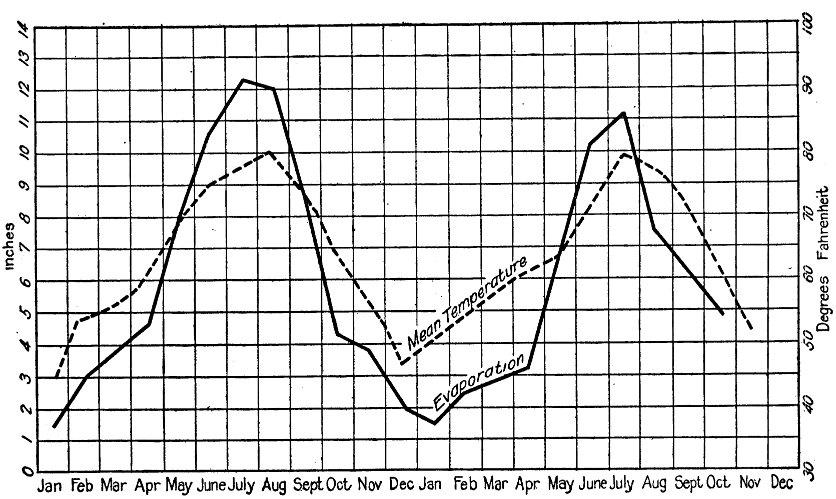

FIG. 32.—Relation between temperature and evaporation from a water surface at Tulare, Cal.

from 20 to 40 per cent in the course of 3 weeks. In order to reduce this loss and moisten the soil around the roots of trees, the practice of running small streams of water in deep furrows has become quite common. In applying water in this way the topsoil remains at least partially dry, the bulk of the water soon passes beyond the first foot, and the surface can be cultivated soon after the water is turned off.

[1] U. S. Dept. of Agr., Office Expt. Stas. Bull. 177 and 248.

However, the prevention of waste of irrigation water by evaporation from the surface of moist soil is only one factor in the profitable production of citrus fruits. If the best conditions for the tree and its fruit can be secured by other methods of applying water they should be adopted, although a part of the water supply may be sacrificed in so doing.

The well-known effect of temperature on evaporation is shown in figure 32. The dotted line shows the mean monthly temperatures at Tulare, Cal., from January 1, 1904, to December 31, 1905, and the solid line the monthly evaporation from a water surface for the same time.

EFFECT OF SOIL MULCHES IN CHECKING EVAPORATION.

Evaporation as affected by a layer of dry granular soil when placed above moist soil has been shown by a series of experiments conducted in tanks by irrigation investigations of the Bureau of Public Roads. These tanks are water-jacketed and placed in the open under normal conditions as regards sunshine, wind, and temperature. Each tank holds about three-fourths of a ton of soil and is weighed at stated intervals in a manner shown in figure 33.

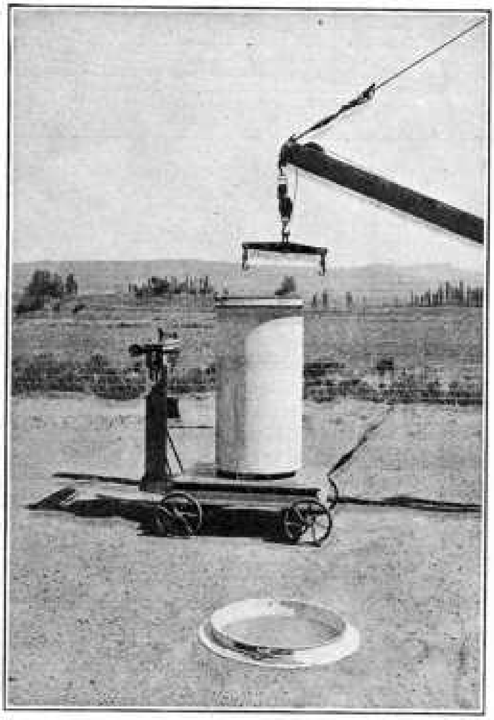

FIG. 33.—Tank experiments at Reno, Nev., to determine effect of soil mulches in checking evaporation.

At five stations in the arid region tanks containing soil were irrigated to a depth of 6 inches. After the water had disappeared entirely from the soil surface fine, dry, granular soil mulches were added as follows: Tanks 1 and 2, no mulch; tanks 3 and 4, a 3-inch layer; tanks 5 and 6, a 6-inch layer; tanks 7 and 8, a 9-inch layer. Weighings were started immediately and continued semiweekly for a period of 21 days. The average losses of water at the five stations are shown, graphically, in figure 34.

Similar equipment was used to determine the effect of cultivation in checking evaporation. The results of experiments conducted at

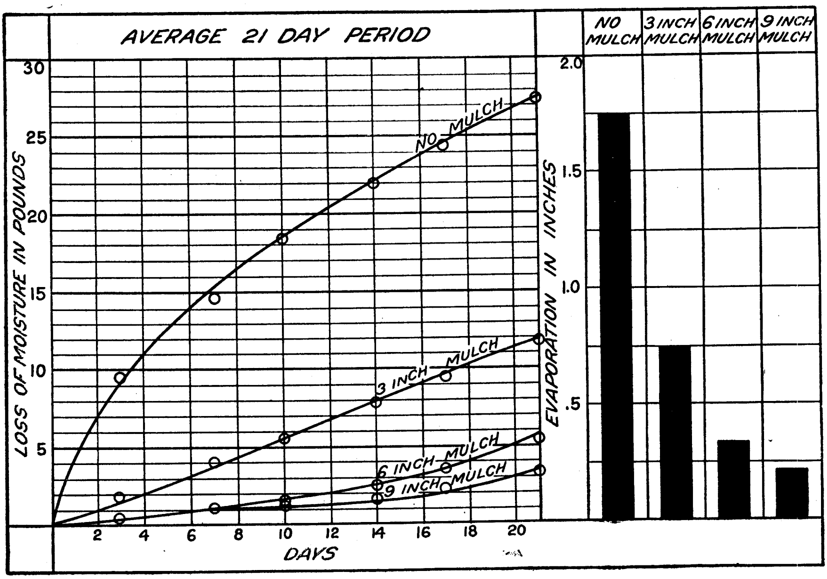

FIG. 34.—Average evaporation losses from tanks of soil protected with mulches of different depths during first 21 days after irrigation. Average of losses at five stations.

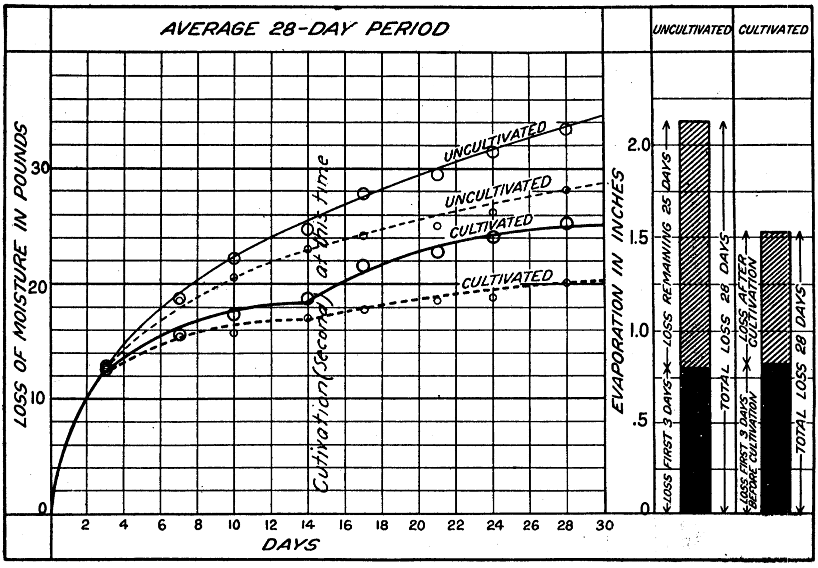

FIG. 35.—Average evaporation losses from cultivated and uncultivated tanks during first 28 days after irrigation; average of losses at six stations.

six stations in the arid region, with the accompanying meteorological data, are given in figure 35. The average losses shown by the above are 2.14 inches from the uncultivated and 1.58 inches from the cultivated soils, being 35.5 and 26.3 per cent, respectively, of the total 6 inches used in irrigation. It is a significant fact that 51 per cent of the losses from the cultivated surface occurred in the first 3 days—that is, during the average period between irrigation and cultivation.

The foregoing shows the influence of dry soil mulches artificially created in checking evaporation. On the other hand, they fail to show that under field conditions the soil mulches must be deprived of the greater part of their moisture by evaporation before becoming dry and consequently effective in conserving the moisture in the soil beneath.

LOSS OF WATER DUE TO PERCOLATION.

In the preceding paragraphs attention has been called to the large amount of water which is vaporized from warm, moist soils. The above heading calls attention to another loss of a different character. In all modes of wetting the soil, but more particularly when deep furrows are used to distribute the water, a part is likely to sink beyond the deepest roots. As a rule, the longer the furrow the greater is the loss from this cause. In furrows about one-eighth of a mile long Dr. Loughridge found in his experiments at Riverside, Cal., that in some parts of the orchard the soil was wet as a result of a recent irrigation to depths of 20 to 26 feet, while in other parts the moisture had not penetrated beyond the third foot.

One of the best ways of finding out whether much water is lost by deep percolation is to dig trenches across the furrows as deep as the feeding roots go. The moisture which passes the deepest roots in its downward course may be considered wasted.

An example of fairly even and desirable moisture distribution from furrows in orchard irrigation is shown in Sections XI and XII of figure 36, where the three curved lines show the margins of the wetted soil at the end of 1, 2, and 3 days, respectively. This diagram, likewise, shows that the irrigation is defective in having dry spaces between Sections IV and V, X and XI, and XII and XIII. Since the lateral movement of moisture in soils proceeds very slowly after the third day from an irrigation, it is doubtful that these dry spaces receive much water from the adjacent furrows.

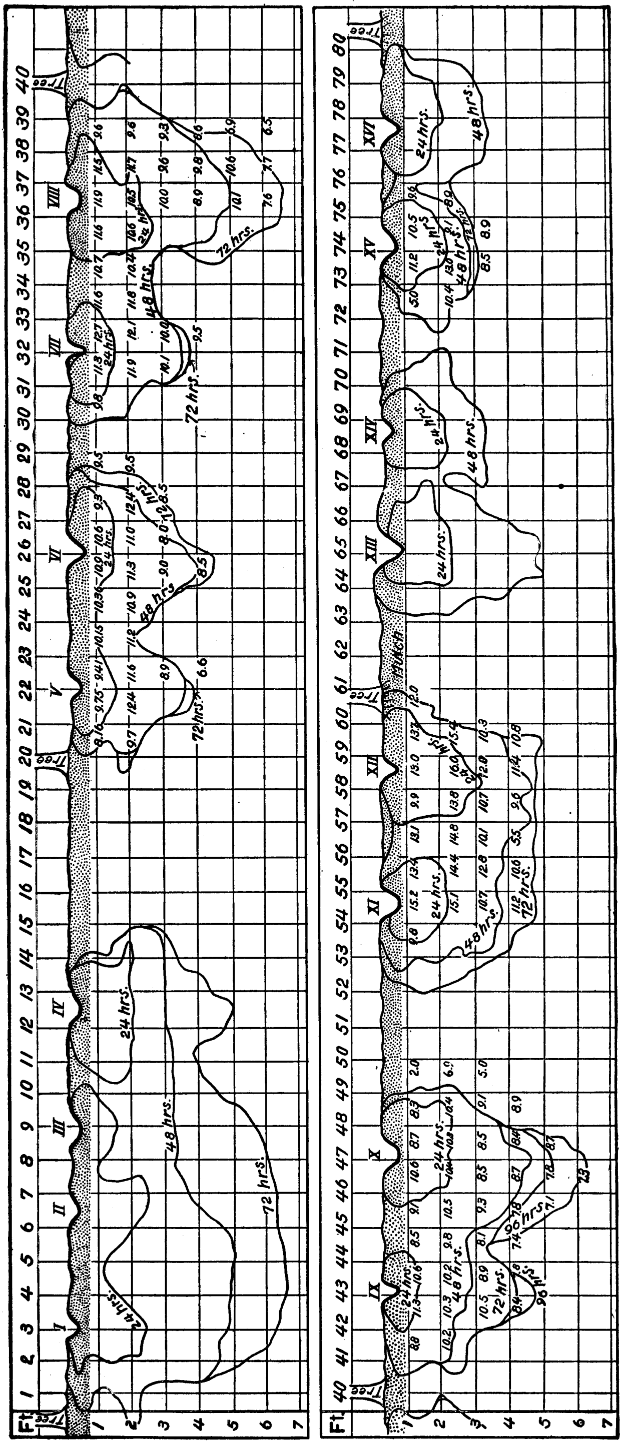

FIG. 36.—Outlines of percolation under 16 furrows in orchard 58 under the Gage Canal Co., Riverside, Cal,

Summary of temperature of air, soil, and water, humidity, wind velocity, rainfall, free water in soil, and losses from free-water surface and from cultivated and uncultivated tanks at the several stations.

Stations.	Number of trials.	Temperatures.				Humidity.	Average wind velocity per hour.	Total rainfall.	Free water in soil.	Evaporation from free-water surface.	Loss from cultivated soils.	Loss from uncultivated soils.	Saved by cultivation.
		Atmospheric.	Cultivated soil.	Uncultivated soil.	Water.								
		° *F.*	° *F.*	° *F.*	° *F.*	*P. ct.*	*Miles.*	*In.*	*P. ct.*	*In.*	*In.*	*In.*	*P. ct.*
Sunnyside, Wash......	1	65.2	71.3	74.3	70.9	......	......	0.00	6.00	7.25	1.47	2.47	40.3
Davis, Cal.............	2	64.5	......	75.7	73.2	49.8	9.3	.00	12.85	9.41	1.36	1.91	28.2
Reno, Nev............	2	56.6	......	67.9	......	58.9	6.4	.39	8.88	8.49	1.09	1.51	27.8
Caldwell, Idaho........	2	72.2	69.2	69.4	68.4	......	......	.14	6.21	9.81	1.91	2.42	21.0
Agricultural College, N. Mex.............	2	74.5	......	......	......	22.7	8.3	.57	......	11.13	1.37	1.59	13.8
Bozeman, Mont.......	1	64.4	73.9	74.6	75.0	......	9.4	.99	17.80	4.38	2.30	2.92	21.2
Average..........	....	66.2	71.5	72.4	72.9	43.8	8.4	.35	10.35	8.41	1.58	2.14	26.4

REMOVAL OF WASTE WATER.

Loss of water is not the only effect of deep percolation. The water which escapes in this and other ways usually moves through the soil slowly until it reaches some underground body of water at a lower level. In case orchards have been planted at these lower levels when the subsoil was dry, care should be exercised in observing the rise of the ground-water level. The small post-hole auger shown in figure 37 is one of the most convenient tools to use in making test wells to keep track of the behavior of the ground water. Before the deepest roots of the fruit trees are submerged artificial drainage ought to be provided. Otherwise the ground water will at first lessen the yield and finally destroy the trees.

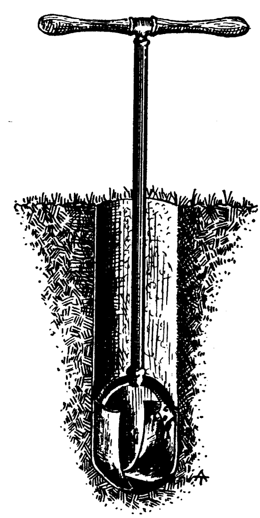

FIG. 37.—Soil auger used to locate ground-water level.

The drainage of orchard tracts usually progresses in more or less distinct and separate stages. When the ground water begins to be a menace, the natural ravines in the vicinity are cleared of weeds and other rubbish and deepened. If the ground water continues to rise, the open drains are deepened and extended or else the excess water is withdrawn through covered drains. Open drains in orchards occupy valuable land, obstruct field work, and are expensive to maintain. Some of these objections can be lessened if not removed by locating such drains along the lower boundary of the tract. When this plan is followed, covered drains frequently are laid among the trees and discharge into the open drains. Sometimes the source and direction of the waste water which is waterlogging an orchard can be traced beneath the

surface. In this event it is well to try to intercept its passage before it reaches the trees. This can be done by an open drain, but a covered pipe drain of the required size is preferable. Pipe drains may be made of either clay or cement, but cement tile as at present manufactured is not recommended for the drainage of alkali soils. The former is most frequently used for sizes ranging from 4 to 8 inches in diameter and the latter for sizes 10 inches and over. The clay tile drains are made 1 foot in length, but in using cement for the larger sizes the length may be increased to 2 and even 3 feet.

The drainage of irrigated lands differs in many respects from that common to the humid States of Iowa, Illinois, and Ohio. In irrigated districts the drains are larger and are laid deeper. While 4-inch tile drains may be used in places, 6-inch drains are to be preferred, and should be considered as the smallest desirable size. The depth at which they are laid ranges from 5 to 7 feet, and a minimum of 5 to 6 feet is required for orchards. A grade of 5 feet to the mile is about the least that should be used, and wherever practicable it should be increased to 10 feet to the mile.

In laying drains that are likely to become clogged with silt or roots, or both, a small cable is laid in each line, and at distances of 300 to 500 feet sand boxes similar to figure 38 are placed so as to facilitate cleaning the tiles with suitable wire brushes.

INFLUENCE EXERTED BY TIME OF IRRIGATION.

In 1911 cooperative irrigation investigations were begun in Utah by W. W. McLaughlin, of the Bureau of Public Roads, to determine the influence exerted on peach trees and fruit by varying the time of irrigation. This work was continued until the close of the season of 1914 and the results summarized by L. D. Batchelor in Bulletin 142 of the Utah Agricultural Experiment Station. From this summary the following conclusions are drawn:

1. Frequent applications of irrigation water applied to peaches on a gravel loam soil at intervals of 7 or 8 days produced a more continuous and greater total twig growth than the same total amount of water applied with larger applications at intervals of every 10 to 12 days. The more porous the soil the more frequently the trees should be watered.

2. With varying times of application of irrigation water the season of most rapid twig growth is during the season of watering.

3. A total application of irrigation water of 21 acre-inches per acre on a gravel loam soil produced a total twig growth practically equal to that produced by 62 acre-inches of water per acre.

4. With the same total amount of water applied on a gravel loam there is a regular increase in crop production the more frequent the irrigation. Less water was evidently lost by seepage when irrigation water was applied every 7 or 8 days and the trees received no

check in growth due to becoming excessively dry from one watering to another.

5. The maximum duty of irrigation water applied to peaches on a gravelly soil was 31 acre-inches per acre during the years 1913 and 1914. Sixty-two acre-inches of water applied to 2 acres on a gravel loam soil would apparently have produced twice the yield of marketable fruit than if applied to 1 acre of trees.

6. No amount of water applied early in the season to a crop of peaches on a gravelly soil will compensate for the lack of water during the month before harvest.

7. There is no marked variation in the color of the fruit on the plots receiving a large amount of irrigation water when compared with plots receiving only a medium amount of water. Poor color of the fruit was associated with a small amount of irrigation water.

8. High coloration of the peach was associated with late watering.

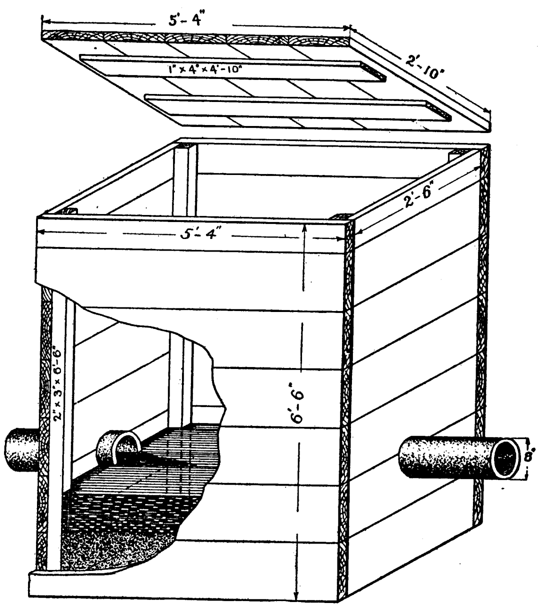

FIG. 38.—Sand box in tile line.

WINTER IRRIGATION OF ORCHARDS.

When water is used outside of the regular irrigation period or, what is in many cases equivalent, outside of the growing season, it is termed winter irrigation. Over a large part of the arid region the growing season is limited by low temperatures to 150 days, or less, and when the flow of streams is utilized only during this period much valuable water runs to waste.

For the purpose of utilizing some of this waste the orchardists of the Pacific Coast States and Arizona began the practice of winter irrigation. The precipitation usually occurs in winter in the form of rain, and large quantities of creek water are then available. This water is spread over the orchards in January, February, and March, when deciduous trees are dormant. The most favorable conditions for this practice are a mild winter climate; a deep, retentive soil that will hold the greater part of the water applied; deep-rooted trees; and a soil moist from frequent rains.

The creek water that was applied to some of the prune orchards of the Santa Clara Valley, Cal., during the winter of 1904 was measured by the agents of this bureau, with the following results: From February 27 to April 23, 1,241 acres were irrigated under the Statler ditch to an average depth of 1.58 feet. From February 12 to April 23, 2,021 acres were irrigated under the Sorosis and Calkins ditches to an average depth of 1.75 feet. In the majority of cases the orchards which are irrigated in winter in this valley receive no additional supply of moisture other than about 16 inches of rain water.

In the colder parts of the arid region winter irrigation is likewise being practiced with satisfactory results. The purpose is not only to store water in the soil but to prevent the winterkilling of trees. Experience has shown that it is not best to apply much water to orchards during the latter part of the growing season, since it tends to produce immature growth which easily is damaged by frost. In many of the orchards of Montana no water is applied in summer irrigation after August 20. Owing, however, to the prevalence of warm chinook winds, which not only melt the snow in a night, but rob the exposed soil of much of its moisture, one or two irrigations are frequently necessary in midwinter.

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